Patterns of Ash Mortality and Regeneration in the Huron River Watershed in Southeast Michigan in Response to the Emerald Ash Borer Invasion

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We have monitored progression of ash (*Fraxinus* spp.) decline and mortality due to emerald ash borer (EAB, *Agrilus planipennis*) in 38 forest stands in the Upper Huron River watershed of southeastern Michigan since 2003. Black (*F. nigra*), green (*F. pennsylvanica*), and white (*F. americana*) ash were most common in hydric, mesic, and xeric stands, respectively. A transect was established within each stand consisting of three 0.1 ha circular plots (114 plots total). Within each plot, all ash trees were identified to species and assigned a crown dieback rating on a scale of 1-5, with '1' indicating no decline and '5' being a dead tree.

Ash decline significantly increased over time from a mean rating of 3.5 in 2004-2005 to 4.8 in 2007, to 4.9 in 2008. Although black ash initially experienced greater decline and mortality than white or green ash in 2004-2005, this trend was absent in 2007, indicating that all species are now declining at equal rates. Overall ash mortality is now 99.7% in all plots, with the vast majority of surviving trees clustered in the 1-2 inch DBH size class. A significant negative relationship was detected between percent ash tree mortality and distance from the epicenter of the infestation in township of Canton, Michigan from 2004 to 2006, with mortality decreasing 2% with each km away from the epicenter. On average, percent mortality of ash increased 30% over the three years, but the slope of line describing this relationship (2% decrease in mortality per km away from the epicenter) remained unchanged. However, this relationship was no longer significant as of 2007, as mortality of ash in stands farther away from the epicenter now exceeds 99%. The location of all surviving trees has been mapped and reported to Dr. Jennifer Koch at the Delaware lab, whom has collected scion material to evaluate them for resistance as part of her "Lingering Ash" research project.

We have also quantified (1) ash regeneration by sampling the ash seed bank from 2005-2008, (2) ash seedling and sapling dynamics in 2008-2010, and (3) EAB populations in relation to ash density through annual sampling with purple panel traps in 2008 and 2009. Our previous

results have shown that ash are the most common woody species in the seedling and sapling layers of these forests, which has led us to pose these questions: (1) will this regeneration restore ash if EAB is locally extirpated due to depletion of its food resource, or (2) can ash regeneration maintain an EAB population indefinitely as the supply of susceptible saplings is continually replenished? We measured densities of four demographic classes of ash: newly germinated seedlings (cotyledons present), established seedlings (at least one-year-old but less than 25 cm tall), saplings (25 cm tall to DBH of 2.5 cm), and trees large enough to support EAB (DBH > 2.5 cm).

Four years of intensive soil sampling (432 samples / yr) suggests that the ash seed bank in these stands is rapidly depleted as overstory trees die. Small numbers of seeds were found in 2005 and 2006; however, no ash seeds were found in the soil or on the soil surface in 2007 or 2008. Our observations also indicate, contrary to some earlier speculation, that ash trees do not increase seed production as they become stressed by EAB. Patterns of ash demography were consistent with conclusions reached from seed bank sampling. Density of new ash seedlings was 0.5 and 0.1 plant / ha in the Michigan plots in 2008 and 2009, respectively. No new ash seedlings were observed in 2010 inside or outside the monitoring plots. In contrast, density of new ash seedlings routinely exceeded 800 plants / ha in Ohio plots where EAB mortality was still low or nonexistent, and exceeded 20,000 plants / ha in some plots in 2009 following mast seed production on a regional scale in 2008. Established ash seedlings (no cotyledons but less than 25 cm tall) were far more abundant than new seedlings in the Michigan plots, averaging 76 and 191 plants / ha in 2008 and 2009, respectively. However, this pattern was reversed in Ohio plots, where new seedlings greatly exceeded established seedlings, except in stands where mortality of mature ash approached 100%.

Density of ash saplings was much lower (6.1 plants / ha in 2009) than that of established seedlings, possibly due to self-thinning. Density of trees large enough to be colonized by EAB (> 2.5 cm DBH) was less than 1.0 plant / ha in both 2008 and 2009. Numbers of EAB captured on purple panel traps were correlated with percent survival of mature ash, and declined from 2008 to 2009 as ash mortality increased. However, EAB continued to persist at low levels in all plots, suggesting that ash saplings may be sustaining low density populations.

In summary, EAB-induced mortality of trees with DBH > 2.5 cm now exceeds 99% in the Huron River Watershed in southeast Michigan. Our evidence suggests the ash seed bank does not persist after overstory trees succumb. Ash regeneration has ceased in these plots, as new seedlings were virtually nonexistent in 2008 and 2009, averaging less than one plant / ha. Established seedlings and saplings with DBH < 2.5 cm are the only demographic classes of ash remaining in these plots. EAB continues to persist at low levels even in plots where ash mortality exceeds 99%, suggesting that an EAB population might be sustained, at least in the short-term, as established seedlings and saplings become large enough to be colonized. Ultimately, in the absence of ash regeneration, EAB may be locally extirpated as this orphaned cohort of juvenile ash is gradually depleted via EAB mortality.